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Todoroki

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(54) **PNEUMATIC TIRE**

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ABSTRACT

In a tire 2 of the present invention, sidewalls 6 each include an outer layer 6a, and an inner layer 6b disposed inward of the outer layer 6a in the axial direction. The inner side end, in the radial direction, of the inner layer 6a extends to a region between a bead 10 and a chafer 8. When Po represents a contact point, on an outer surface of the tire 2, at which the outer layer 6a and the chafer 8 contact with each other, an inner side end, in the radial direction, of the outer layer 6a is equal to the contact point Po. In the radial direction, an outer side end 44 of the chafer 8 is disposed outward of the contact point Po. In the radial direction, an inner side end 46 of the inner layer 6b is disposed inward of the contact point Po.

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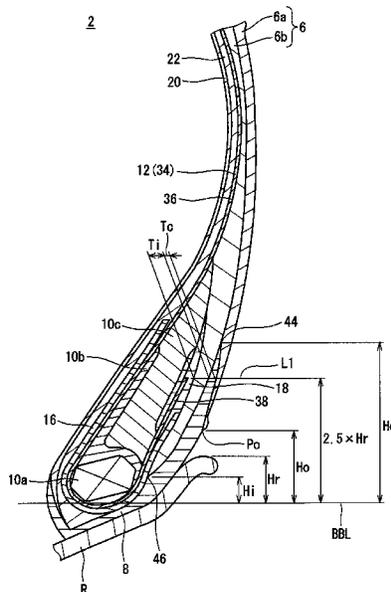
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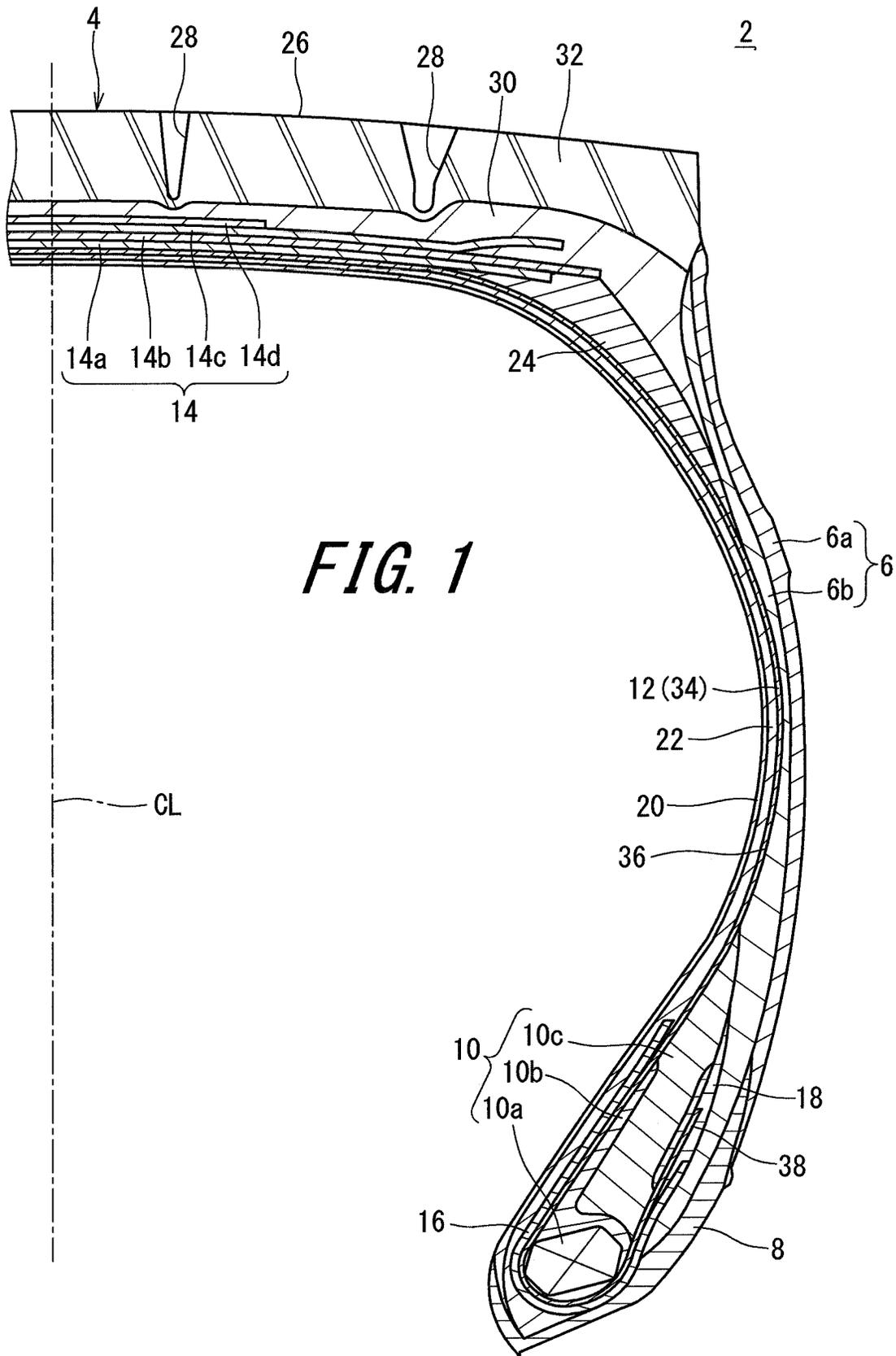
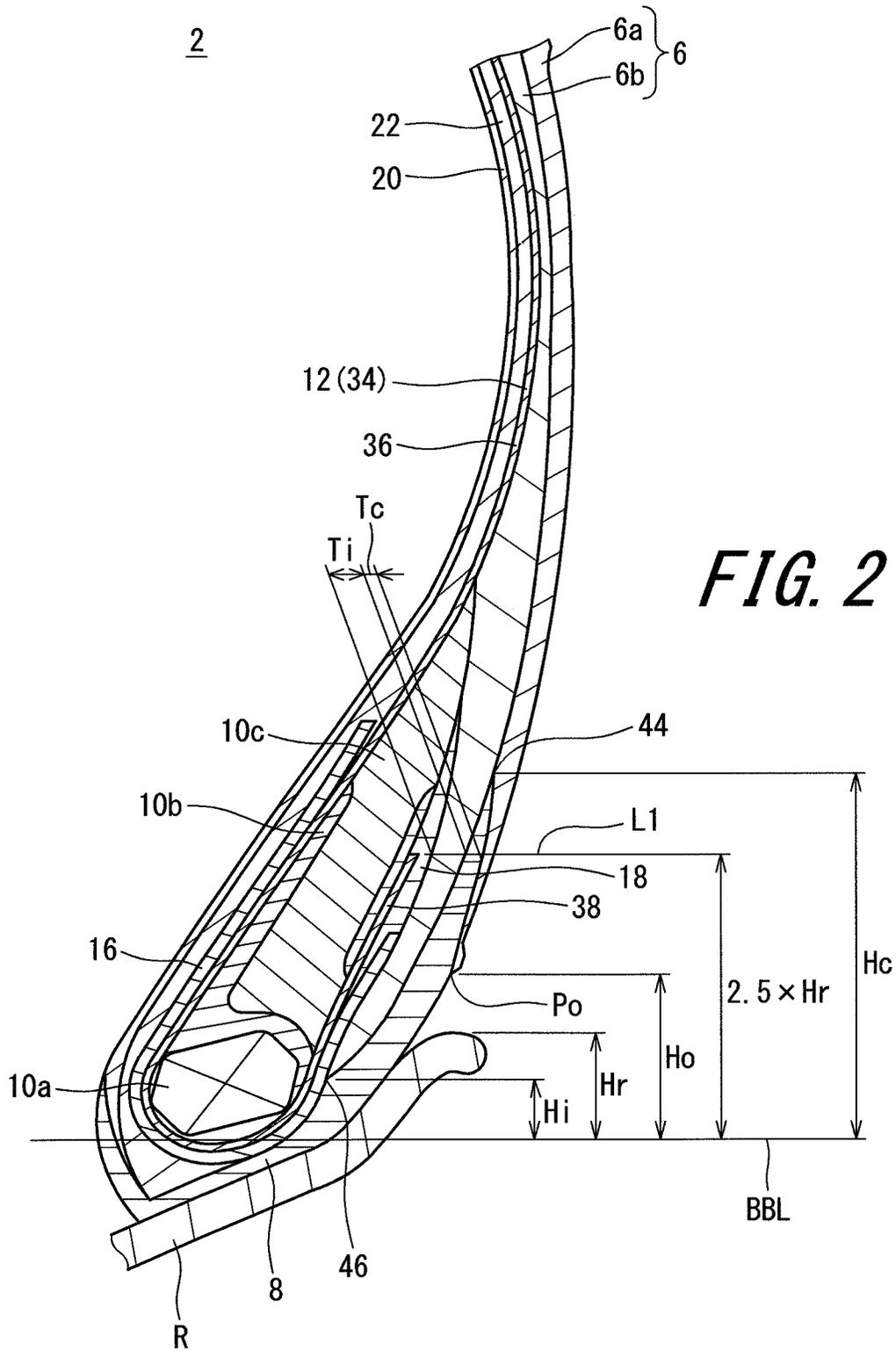


FIG. 1



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PNEUMATIC TIRE

This application claims priority on Patent Application No. 2016-018050 filed in JAPAN on Feb. 2, 2016. The entire contents of this Japanese Patent Application are hereby incorporated by reference.

BACKGROUND OF THE INVENTION**Field of the Invention**

The present invention relates to pneumatic tires. More specifically, the present invention relates to heavy duty pneumatic tires which are to be mounted to vehicles such as trucks, buses, and the like.

Description of the Related Art

In recent years, reduction of fuel consumption is particularly strongly required for vehicles in consideration of the environment. Tires exert influence on fuel efficiency of vehicles. Therefore, development of a "fuel-efficient tire" that contributes to reduction of fuel consumption is advanced. In order to achieve, by a tire, reduction of fuel consumption, it is important to reduce rolling resistance of the tire. When a tire rolls, deformation and restoration are repeated. Energy loss caused by the deformation and restoration is a main cause of rolling resistance of the tire. Reduction of the energy loss is important for reducing rolling resistance. Reduction of the energy loss in sidewalls is also required.

A tire in which energy loss is reduced in sidewalls is disclosed in JP2007-196988 (US2007/0151649). In the tire, each sidewall has a two-layer structure that includes an outer rubber portion and an inner rubber portion. The inner rubber portion is formed of rubber (low heat generating rubber) having a loss tangent that is less than that of conventional rubber, whereby rolling resistance is reduced. The outer rubber portion is formed of rubber having a loss tangent and a complex elastic modulus that are higher than those of the inner rubber portion, whereby reduction of durability is inhibited.

Increased reduction of rolling resistance is required since reduction of fuel consumption is highly required for vehicles. In addition, tires are required to maintain high durability.

In order to further reduce rolling resistance, a method for increasing the proportion of low heat generating rubber used for a tire may be considered. This can be realized by the inner rubber of sidewalls being extended to bead portions. However, heavy load is applied to the bead portions from a rim. Chafers have a complex elastic modulus that is higher than that of the sidewalls in order to protect the bead portions. If the inner rubber having low complex elastic modulus and loss tangent is extended to the bead portions, strain in the portions may be increased. This may cause generation of cracks in an interface between the outer rubber and the chafer. This may cause reduction of durability of the tire.

An object of the present invention is to provide a pneumatic tire that allows rolling resistance to be further reduced, and also allows high durability to be achieved.

SUMMARY OF THE INVENTION

A pneumatic tire according to the present invention includes: a tread having an outer surface which forms a tread

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surface; a pair of sidewalls that extend almost inward from ends, respectively, of the tread in a radial direction; chafers disposed inward of the sidewalls, respectively, in the radial direction; and a pair of beads disposed inward of the chafers, respectively, in an axial direction. The sidewalls each include an outer layer, and an inner layer disposed inward of the outer layer in the axial direction. The inner layer extends to a region between a corresponding one of the beads and a corresponding one of the chafers. The outer layer contacts with a corresponding one of the chafers. When P_o represents a contact point, on an outer surface of the tire, at which the outer layer and a corresponding one of the chafers contact with each other, an inner side end, in the radial direction, of the outer layer is equal to the contact point P_o . In the radial direction, an outer side end of each chafer is disposed outward of the contact point P_o . In the radial direction, an inner side end of the inner layer is disposed inward of the contact point P_o . A loss tangent LT_i of the inner layer is less than a loss tangent LT_o of the outer layer and a loss tangent LT_c of the chafers.

The inventors have examined in detail a structure of the sidewalls each of which includes: the inner layer having a low loss tangent; and the outer layer having a loss tangent higher than the inner layer. As a result, it has been found that, even if the inner layer is extended to the bead portion, in a case where a position of the inner layer and a position of a boundary between the outer layer and the chafer are appropriately adjusted, durability can be advantageously maintained.

In the tire according to the present invention, the sidewalls each include the inner layer and the outer layer. The loss tangent of the inner layer is less than the loss tangents of the outer layer and the chafer. The inner layer is formed of low heat generating rubber. The inner layer extends to a region between the bead and the chafer. The inner layer is extended to the bead portion. The proportion of the low heat generating rubber used for the tire is greater than that for conventional tires. In the tire, rolling resistance is reduced. Further, the inner layer allows heat generation in the bead portion to be reduced. This inhibits reduction of durability of the bead portion. In the tire, durability is advantageously maintained.

In the tire, when P_o represents a contact point, on the outer surface of the tire, at which the outer layer and the chafer contact with each other, the inner side end, in the radial direction, of the outer layer is equal to the contact point P_o . In the radial direction, the outer side end of the chafer is disposed outward of the contact point P_o , and the inner side end of the inner layer is disposed inward of the contact point P_o . That is, in a region between the contact point P_o and the outer side end of the chafer in the radial direction, the chafer is disposed between the outer layer and the inner layer. In this structure, even if the inner layer extends to the bead portion, strain at the interface between the outer layer and the chafer is reduced. In the tire, generation of cracks at the interface between the outer layer and the chafer is inhibited. In the tire, durability is advantageously maintained.

Preferably, a ratio (H_i/H_r) of a height H_i , in the radial direction, from a bead base line BBL to the inner side end of the inner layer, relative to a height H_r , in the radial direction, from the bead base line BBL to an outer side end of a flange of a rim on which the tire is mounted, is greater than or equal to 0.0 and not greater than 1.5.

Preferably, when H_r represents a height, in the radial direction, from a bead base line BBL to an outer side end of a flange of a rim on which the tire is mounted, L_1 represents

an imaginary line that extends in the axial direction such that a distance, in the radial direction, from the bead base line BBL to the imaginary line L1 is 2.5 times the height Hr, Ti represents a thickness, of the inner layer, measured along the imaginary line L1, and Tc represents a thickness, of each chafer, measured along the imaginary line L1, a ratio (Ti/Tc) of the thickness Ti to the thickness Tc is greater than or equal to 0.5 and not greater than 1.5.

Preferably, when Hr represents a height, in the radial direction, from a bead base line BBL to an outer side end of a flange of a rim on which the tire is mounted, and Ho represents a height, in the radial direction, from the bead base line BBL to the contact point Po, a ratio (Ho/Hr) of the height Ho to the height Hr is greater than or equal to 1.5 and not greater than 3.0.

Preferably, when Hr represents a height, in the radial direction, from a bead base line BBL to an outer side end of a flange of a rim on which the tire is mounted, and Hc represents a height, in the radial direction, from the bead base line BBL to the outer side end of each chafer, a ratio (Hc/Hr) of the height Hc to the height Hr is greater than or equal to 3.0 and not greater than 5.0.

Preferably, the loss tangent LTi is higher than or equal to 0.02 and not higher than 0.05.

Preferably, the loss tangent LTo is higher than or equal to 0.05 and not higher than 0.10.

Preferably, the loss tangent LTc is higher than or equal to 0.10 and not higher than 0.30.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a part of a tire according to one embodiment of the present invention; and FIG. 2 is an enlarged cross-sectional view of a part of the tire shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following will describe in detail the present invention based on preferred embodiments with reference where appropriate to the accompanying drawing.

FIG. 1 shows a pneumatic tire 2. In FIG. 1, the up-down direction represents the radial direction of the tire 2, the left-right direction represents the axial direction of the tire 2, and the direction perpendicular to the surface of the drawing sheet represents the circumferential direction of the tire 2. In FIG. 1, an alternate long and short dash line CL represents the equator plane of the tire 2. The shape of the tire 2 is symmetric about the equator plane except for a tread pattern.

The tire 2 includes a tread 4, sidewalls 6, chafers 8, beads 10, a carcass 12, a belt 14, fillers 16, cover rubbers 18, an inner liner 20, an insulation 22, and cushion layers 24. The tire 2 is of a tubeless type. The tire 2 is mounted to a truck, a bus, or the like. The tire 2 is a heavy duty tire.

The tread 4 has a shape that projects outward in the radial direction. The tread 4 forms a tread surface 26 that can contact with a road surface. The tread surface 26 has grooves 28 formed therein. A tread pattern is formed by the grooves 28. The tread 4 includes a base layer 30 and a cap layer 32. The cap layer 32 is disposed outward of the base layer 30 in the radial direction. The cap layer 32 is layered over the base layer 30. The base layer 30 is formed of crosslinked rubber excellent in adhesiveness. A typical base rubber of the base layer 30 is natural rubber. The cap layer 32 is formed of crosslinked rubber excellent in wear resistance, heat resistance, and grip performance.

The sidewalls 6 extend almost inward from ends of the tread 4 in the radial direction. As shown in FIG. 1, each sidewall 6 includes an outer layer 6a and an inner layer 6b.

The outer layer 6a forms a part of an outer surface of the tire 2. The outer layer 6a is disposed outward of the inner layer 6b in the axial direction. Near the radially inner side ends of the outer layers 6a, the outer layers 6a contact with the chafers 8. The outer layer 6a is formed of crosslinked rubber excellent in external damage resistance and weather resistance.

The inner layer 6b is disposed inward of the outer layer 6a in the axial direction. The inner layer 6b contacts with the axially inner side surface of the outer layer 6a. The inner layer 6b extends to a region between the bead 10 and the chafer 8. The radially inner side end of the inner layer 6b is disposed outward of the bead 10 in the axial direction. The radially inner side end of the inner layer 6b is disposed inward of the chafer 8 in the axial direction.

The outer layer 6a and the inner layer 6b are more flexible than the chafers 8. A complex elastic modulus Eo* of the outer layer 6a and a complex elastic modulus Ei* of the inner layer 6b are less than a complex elastic modulus Ec* of the chafers 8. The flexible outer layer 6a and inner layer 6b contribute to excellent ride comfort.

In the tire 2, a loss tangent LTi of the inner layer 6b is less than a loss tangent LTo of the outer layer 6a and a loss tangent LTc of the chafers 8. The inner layer 6b is formed of low heat generating rubber.

In the present invention, the loss tangents LTi, LTo, and LTc and the complex elastic moduli Ei*, Eo*, and Ec* are measured in compliance with the standard of "JIS K 6394", by using a viscoelasticity spectrometer ("VESF-3" manufactured by Iwamoto Seisakusho), under the following conditions.

Initial strain: 10%

Amplitude: $\pm 2.0\%$

Frequency: 10 Hz

Deformation mode: tension

Measurement temperature: 30° C.

Each chafer 8 is disposed almost inward of the outer layer 6a in the radial direction. The chafers 8 are disposed outward of the beads 10 and the carcass 12 in the axial direction. When the tire 2 is mounted on a rim, the chafers 8 contact with the rim. By the contact, portions near the beads 10 are protected. Therefore, the chafers 8 are harder than the sidewalls 6. The chafers 8 are formed of crosslinked rubber excellent in wear resistance. The complex elastic modulus Ec* of the chafers 8 is higher than the complex elastic modulus Ei* of the inner layer 6b and the complex elastic modulus Eo* of the outer layer 6a. The loss tangent LTc of the chafers 8 is higher than the loss tangent LTi of the inner layer 6b and the loss tangent LTo of the outer layer 6a.

The beads 10 are disposed inward of the sidewalls 6 in the radial direction. Each bead 10 includes a core 10a, an apex 10b that extends outward from the core 10a in the radial direction, and a packing rubber 10c that extends outward from the apex 10b in the radial direction. The core 10a is ring-shaped. The core 10a includes a plurality of non-stretchable wires. The apex 10b is tapered outward in the radial direction. The apex 10b is formed of highly hard crosslinked rubber. The packing rubber 10c is tapered outward in the radial direction. The packing rubber 10c is flexible. The packing rubber 10c reduces concentration of stress on the end of the carcass 12.

The carcass 12 includes a carcass ply 34. The carcass ply 34 is extended on and between the beads 10 on both sides, along inner sides of the tread 4 and the sidewalls 6. The

carcass ply **34** is turned up around the cores **10a** from the inner side toward the outer side in the axial direction. By the turning-up, the carcass ply **34** includes a main portion **36** and turned-up portions **38**.

The carcass ply **34** includes multiple cords aligned with each other, and topping rubber, which is not shown. An absolute value of an angle of each cord relative to the equator plane is from 45° to 90°, and more preferably from 75° to 90°. In other words, the carcass **12** forms a radial structure. The cords are formed of steel. The carcass **12** may include two or more carcass plies **34**.

The belt **14** extends in the axial direction on the cross section obtained by cutting the tire **2** at a plane perpendicular to the circumferential direction. The belt **14** is disposed inward of the tread **4** in the radial direction. The belt **14** is disposed outward of the carcass **12** in the radial direction. The belt **14** reinforces the carcass **12**. In the tire **2**, the belt **14** includes a first layer **14a**, a second layer **14b**, a third layer **14c**, and a fourth layer **14d**.

In the tire **2**, the ends of the second layer **14b** are disposed outward of the ends of the first layer **14a** in the axial direction. The ends of the second layer **14b** are disposed outward of the ends of the third layer **14c** in the axial direction. The ends of the second layer **14b** are disposed outward of the ends of the fourth layer **14d** in the axial direction. In the tire **2**, among the first layer **14a**, the second layer **14b**, the third layer **14c**, and the fourth layer **14d** of the belt **14**, the second layer **14b** has the largest width. In the tire **2**, the ends of the second layer **14b** are the ends of the belt **14**.

Each of the first layer **14a**, the second layer **14b**, the third layer **14c**, and the fourth layer **14d** includes multiple cords aligned with each other, and topping rubber, which is not shown. Each cord is formed of steel. The cords tilt relative to the equator plane. An absolute value of an angle of each cord relative to the equator plane is from 15° to 70°.

The fillers **16** are turned up around the cores **10a** of the beads **10**, respectively. A first end of each filler **16** is disposed inward of the bead **10** in the axial direction. A second end of each filler **16** is disposed outward of the bead **10** in the axial direction. The fillers **16** are layered over the carcass ply **34**. Each filler **16** includes multiple cords aligned with each other, and topping rubber. Each cord is formed of steel. The filler **16** is referred to also as a steel filler **16**. The fillers **16** can contribute to durability of the tire **2**.

Each cover rubber **18** is disposed outward of the apex **10b** in the axial direction. The cover rubbers **18** cover the ends of the turned-up portions **38** of the carcass ply **34**, as illustrated in the drawings.

The inner liner **20** forms an inner surface of the tire **2**. The inner liner **20** is formed of crosslinked rubber. For the inner liner **20**, rubber excellent in airtightness is used. A typical base rubber of the inner liner **20** is isobutylene-isoprene-rubber or halogenated isobutylene-isoprene-rubber. The inner liner **20** maintains internal pressure of the tire **2**.

The insulation **22** is disposed outward of the inner liner **20**. The insulation **22** is disposed inward of the carcass **12**. The insulation **22** is disposed between the carcass **12** and the inner liner **20**. The insulation **22** is formed of crosslinked rubber excellent in adhesiveness. The insulation **22** is joined firmly to the carcass **12**, and is also joined firmly to the inner liner **20**. The insulation **22** allows separation of the inner liner **20** from the carcass **12** to be inhibited.

The cushion layers **24** are layered over the carcass **12** near the ends of the belt **14**. The cushion layers **24** are formed of flexible crosslinked rubber. The cushion layers **24** absorb

stress at the ends of the belt **14**. The cushion layers **24** allow lifting of the belt **14** to be inhibited.

FIG. **2** is an enlarged cross-sectional view of the tire **2** shown in FIG. **1** and illustrates a bead **10** portion. In FIG. **2**, the up-down direction represents the radial direction, the left-right direction represents the axial direction, and the direction perpendicular to the surface of the drawing sheet represents the circumferential direction. In FIG. **2**, reference character **R** represents a rim on which the tire **2** is mounted. In FIG. **2**, the tire **2** is mounted on the rim **R**. A solid line **BBL** represents a bead base line. The bead base line **BBL** corresponds to a line that defines a rim diameter of the rim **R** (see **JATMA**). The bead base line **BBL** extends in the axial direction.

In FIG. **2**, reference character **Po** represents a contact point, on the outer surface of the tire **2**, at which the outer layer **6a** and the chafer **8** contact with each other. The contact point **Po** is equal to the inner side end, in the radial direction, of the outer layer **6a**. In the radial direction, an outer side end **44** of the chafer **8** is disposed outward of the contact point **Po**. In a region between the contact point **Po** and the outer side end **44** of the chafer **8** in the radial direction, the outer layer **6a** and the chafer **8** overlap each other in the axial direction. In this region, the chafer **8** is disposed inward of the outer layer **6a** in the axial direction.

As described above, the inner layer **6b** extends to a region between the bead **10** and the chafer **8**. In the radial direction, an inner side end **46** of the inner layer **6b** is disposed inward of the contact point **Po**. In the region between the contact point **Po** and the outer side end **44** of the chafer **8** in the radial direction, the outer layer **6a**, the chafer **8**, and the inner layer **6b** overlap each other in the axial direction. In this region, the chafer **8** is disposed between the outer layer **6a** and the inner layer **6b**.

Hereinafter, an action and effect of the present invention will be described.

In the tire **2** according to the present invention, as described above, each sidewall **6** includes the inner layer **6b** and the outer layer **6a**. The loss tangent **LTi** of the inner layer **6b** is less than the loss tangent **LTo** of the outer layer **6a** and the loss tangent **LTC** of the chafers **8**. The inner layer **6b** is formed of low heat generating rubber. The inner layer **6b** extends to a region between the bead **10** and the chafer **8**. The inner layer **6b** extends to the bead **10** portion. The proportion of the low heat generating rubber used for the tire **2** is greater than that for conventional tires. In the tire **2**, rolling resistance is reduced. Further, the inner layer **6b** allows reduction of heat generation in the bead **10** portion. This inhibits reduction of durability in the bead **10** portion. In the tire **2**, durability is advantageously maintained.

In the tire **2**, as described above, when **Po** represents the contact point, on the outer surface of the tire **2**, at which the outer layer **6a** and the chafer **8** contact with each other, the inner side end, in the radial direction, of the outer layer **6a** is equal to the contact point **Po**. In the radial direction, the outer side end **44** of the chafer **8** is disposed outward of the contact point **Po**, and the inner side end **46** of the inner layer **6b** is disposed inward of the contact point **Po**. That is, in a region between the contact point **Po** and the outer side end **44** of the chafer **8** in the radial direction, the chafer **8** is disposed between the outer layer **6a** and the inner layer **6b**. In this structure, even if the inner layer **6b** extends to the bead **10** portion, strain in the interface between the outer layer **6a** and the chafer **8** is reduced. In this structure, even if the inner layer **6b** extends to the bead **10** portion, durability is advantageously maintained in the bead **10** portion. The tire **2** is excellent in durability.

In FIG. 2, a double-headed arrow H_i represents a height, in the radial direction, from the bead base line BBL to the inner side end **46** of the inner layer **6b**. In FIG. 2, a double-headed arrow H_r represents a height, in the radial direction, from the bead base line BBL to an outer side end of a flange of the rim R. A ratio (H_i/H_r) of the height H_i to the height H_r is preferably less than or equal to 1.5. When the ratio (H_i/H_r) is less than or equal to 1.5, the inner layer **6b** allows rolling resistance to be further reduced. In this viewpoint, the ratio (H_i/H_r) is more preferably less than or equal to 1.3. The ratio (H_i/H_r) is preferably not less than 0.0.

When the ratio (H_i/H_r) is not less than 0.0, the inner layer **6b** allows generation of strain in the interface between the filler **16** and the chafer **8** near the inner side portion, in the radial direction, of the bead **10** to be effectively inhibited. In the bead **10** portion, durability is advantageously maintained. In this viewpoint, the ratio (H_i/H_r) is more preferably not less than 0.5. When the ratio (H_i/H_r) is 0.0, the inner side end **46** of the inner layer **6b** is disposed just on the bead base line BBL.

In FIG. 2, a solid line L1 represents an imaginary line that extends in the axial direction. A distance, in the radial direction, between the bead base line BBL and the imaginary line L1 is 2.5 times the height H_r . A double-headed arrow T_i represents a thickness, of the inner layer **6b**, which is measured along the imaginary line L1. That is, the thickness T_i represents a distance, between the inner side surface and the outer side surface of the inner layer **6b**, which is measured along the solid line L1. A double-headed arrow T_c represents a thickness, of the chafer **8**, which is measured along the imaginary line L1. That is, the thickness T_c represents a distance, between the inner side surface and the outer side surface of the chafer **8**, which is measured along the solid line L1.

A ratio (T_i/T_c) of the thickness T_i to the thickness T_c is preferably greater than or equal to 0.5. In the tire **2** in which the ratio (T_i/T_c) is greater than or equal to 0.5, rolling resistance is effectively reduced. In this viewpoint, the ratio (T_i/T_c) is more preferably greater than or equal to 0.7.

The ratio (T_i/T_c) is preferably not greater than 1.5. In the tire **2** in which the ratio (T_i/T_c) is not greater than 1.5, the chafers **8** effectively protect the bead **10** portion. In the tire **2**, durability is advantageously maintained. In this viewpoint, the ratio (T_i/T_c) is more preferably not greater than 1.3.

The thickness T_i is preferably greater than or equal to 2.0 mm. The inner layer **6b** in which the thickness T_i is greater than or equal to 2.0 mm, effectively contributes to reduction of rolling resistance. In this viewpoint, the thickness T_i is more preferably greater than or equal to 2.5 mm.

The thickness T_i is preferably not greater than 5.5 mm. In the tire **2** having the inner layer **6b** in which the thickness T_i is not greater than 5.5 mm, stiffness of the bead **10** portion can be appropriately maintained. Thus, durability is advantageously maintained in the bead **10** portion. In this viewpoint, the thickness T_i is more preferably not greater than 5.0 mm.

The thickness T_c is preferably greater than or equal to 2.0 mm. The chafers **8** in which the thickness T_c is greater than or equal to 2.0 mm, effectively protect the bead **10** portion. In the tire **2**, excellent durability is maintained. In this viewpoint, the thickness T_c is more preferably greater than or equal to 2.5 mm.

The thickness T_c is preferably not greater than 5.5 mm. In the tire **2** having the chafers **8** in which the thickness T_c is not greater than 5.5 mm, rolling resistance is effectively

reduced. In this viewpoint, the thickness T_c is more preferably not greater than 5.0 mm.

In FIG. 2, a double-headed arrow H_o represents a height, in the radial direction, from the bead base line BBL to the contact point P_o . A ratio (H_o/H_r) of the height H_o to the height H_r is preferably less than or equal to 3.0. In the tire **2** in which the ratio (H_o/H_r) is less than or equal to 3.0, stiffness can be appropriately adjusted in the side portion (a portion including both the sidewall **6** and the chafer **8** is referred to as the side portion). The tire **2** is excellent in ride comfort. Further, in the tire **2**, rolling resistance is effectively reduced. In this viewpoint, the ratio (H_o/H_r) is more preferably less than or equal to 2.5.

The ratio (H_o/H_r) is preferably not less than 1.5. In the tire **2** in which the ratio (H_o/H_r) is not less than 1.5, even if the side portion is under a heavy load, the chafer **8** contacts with the flange of the rim R. The outer layer **6a** does not contact with the flange. In the tire **2**, excellent durability is maintained. In this viewpoint, the ratio (H_o/H_r) is more preferably not less than 1.8.

In FIG. 2, a double-headed arrow H_c represents a height, in the radial direction, from the bead base line BBL to the outer side end **44** of the chafer **8**. A ratio (H_c/H_r) of the height H_c to the height H_r is preferably less than or equal to 5.0. In the tire **2** in which the ratio (H_c/H_r) is less than or equal to 5.0, stiffness in the side portions can be appropriately adjusted. The tire **2** is excellent in ride comfort. Further, in the tire **2**, rolling resistance is effectively reduced. In this viewpoint, the ratio (H_c/H_r) is more preferably less than or equal to 4.5.

The ratio (H_c/H_r) is preferably not less than 3.0. In the tire **2** in which the ratio (H_c/H_r) is not less than 3.0, the chafers **8** effectively protect the bead **10** portion. In the tire **2**, excellent durability is maintained. In this viewpoint, the ratio (H_c/H_r) is more preferably not less than 3.5.

The loss tangent L_{Ti} is preferably less than or equal to 0.05. When the loss tangent L_{Ti} is less than or equal to 0.05 in the inner layer **6b**, energy loss can be reduced. In the tire **2**, rolling resistance can be low. In this viewpoint, the loss tangent L_{Ti} is more preferably less than or equal to 0.045.

The loss tangent L_{Ti} is preferably not less than 0.02. In the tire **2** having the inner layer **6b** in which the loss tangent L_{Ti} is not less than 0.02, excellent durability can be maintained in the bead **10** portion. In the tire **2**, high durability is maintained. In this viewpoint, the loss tangent L_{Ti} is more preferably not less than 0.03.

The loss tangent L_{To} is preferably less than or equal to 0.10. In the tire **2** having the outer layer **6a** in which the loss tangent L_{To} is less than or equal to 0.10, energy loss can be reduced. In the tire **2**, rolling resistance can be low. In this viewpoint, the loss tangent L_{To} is more preferably less than or equal to 0.09.

The loss tangent L_{To} is preferably not less than 0.05. The outer layer **6a** in which the loss tangent L_{To} is not less than 0.05, can sufficiently absorb impact from a road surface. The tire **2** is excellent in ride comfort. In this viewpoint, the loss tangent L_{To} is more preferably not less than 0.06.

The loss tangent L_{Tc} is preferably less than or equal to 0.30. In the tire **2** having the chafers **8** in which the loss tangent L_{Tc} is less than or equal to 0.30, energy loss can be reduced. In the tire **2**, rolling resistance can be low. In this viewpoint, the loss tangent L_{Tc} is more preferably less than or equal to 0.28.

The loss tangent L_{Tc} is preferably not less than 0.10. The chafers **8** in which the loss tangent L_{Tc} is not less than 0.10, effectively protect the bead **10** portion. In the tire **2**, high

durability is maintained. In this viewpoint, the loss tangent LT_c is more preferably not less than 0.12.

The complex elastic modulus E_i^* of the inner layer **6b** is preferably higher than or equal to 2 MPa. When the complex elastic modulus E_i^* is higher than or equal to 2 MPa in the inner layer **6b**, a difference between the complex elastic modulus E_i^* of the inner layer **6b** and the complex elastic modulus E_o^* of the outer layer **6a** can be reduced. In the tire **2**, when the tire **2** is under a load, strain in a boundary between the inner layer **6b** and the outer layer **6a** can be reduced. In this viewpoint, the complex elastic modulus E_i^* is more preferably higher than or equal to 2.5 MPa.

The complex elastic modulus E_i^* is preferably not higher than 5 MPa. When the complex elastic modulus E_i^* is not higher than 5 MPa in the inner layer **6b**, stiffness in the side portions can be made appropriate. The tire **2** is excellent in ride comfort and steering stability.

The complex elastic modulus E_o^* of the outer layer **6a** is preferably higher than or equal to 3 MPa. When the complex elastic modulus E_o^* is higher than or equal to 3 MPa in the outer layer **6a**, durability is excellent. In this viewpoint, the complex elastic modulus E_o^* is more preferably higher than or equal to 4 MPa.

The complex elastic modulus E_o^* is preferably not higher than 15 MPa. In the tire **2** having the outer layer **6a** in which the complex elastic modulus E_o^* is not higher than 15 MPa, stiffness in the side portion can be appropriately adjusted. The tire **2** is excellent in ride comfort and steering stability.

The complex elastic modulus E_c^* of the chafer **8** is preferably higher than or equal to 10 MPa. The chafers **8** in which the complex elastic modulus E_c^* is higher than or equal to 10 MPa, effectively protect the bead **10** portion. The tire **2** is excellent in durability. In this viewpoint, the complex elastic modulus E_c^* is more preferably higher than or equal to 15 MPa.

The complex elastic modulus E_c^* is preferably not higher than 90 MPa. In the tire **2** having the chafers **8** in which the complex elastic modulus E_c^* is not higher than 90 MPa, stiffness in the side portion can be appropriately adjusted. The tire **2** is excellent in ride comfort and steering stability.

In the present invention, the dimensions and angles of the tire **2** and each component of the tire **2** are measured in a state where the tire **2** is mounted on a normal rim and inflated with air to a normal internal pressure. During the measurement, no load is applied to the tire **2**. In the description herein, the normal rim represents a rim that is specified according to the standard with which the tire **2** complies. The "standard rim" in the JATMA standard, the "Design Rim" in the TRA standard, and the "Measuring Rim" in the ETRTO standard are normal rims. In the description herein, the normal internal pressure represents an internal pressure that is specified according to the standard with which the tire **2** complies. The "maximum air pressure" in the JATMA standard, the "maximum value" recited in "TIRE LOAD LIMITS AT VARIOUS COLD INFLATION PRESSURES" in the TRA standard, and the "INFLATION PRESSURE" in the ETRTO standard are normal internal pressures. In the description herein, the normal load represents a load that is specified according to the standard with which the tire **2** complies. The "maximum load capacity" in the JATMA standard, the "maximum value" recited in "TIRE LOAD LIMITS AT VARIOUS COLD INFLATION PRESSURES" in the TRA standard, and the "LOAD CAPACITY" in the ETRTO standard, are normal loads.

Example 1

A tire, of example 1, having the structure shown in FIG. **1** was obtained. The size of the tire was 11R22.5. Specifications of the tire are indicated in Table 1. In the tire, the complex elastic modulus E_i^* was 3 MPa, the complex elastic modulus E_o^* was 3 MPa, and the complex elastic modulus E_c^* was 50 MPa, which are not indicated in the table. The thickness T_i was 3 mm and the thickness T_c was 3 mm. Therefore, the ratio (T_i/T_c) was 1.0. The height H_r of a flange of a rim on which the tire was to be mounted was 12.7 mm.

Comparative Example 1

A tire of Comparative example 1 having the specifications indicated in Table 1 was obtained. In the tire, each sidewall had the outer layer and the inner layer, and the inner layer did not extend to the bead portion. This tire was a conventional tire.

Examples 2 to 5 and Comparative Example 2

Tires of examples 2 to 5 and comparative example 2 were each obtained in the same manner as for example 1 except that the height H_i was different, and the ratio (H_i/H_r) was as indicated in Table 1. In example 2, the inner side end of the inner layer reached a portion inward of the bead base line BBL. Therefore, the ratio represents a minus value. In comparative example 2, the position of the inner side end of the inner layer was equal to the contact point P_o in the radial direction.

Examples 6 to 11

Tires of examples 6 to 11 were each obtained in the same manner as for example 1 except that the thickness T_i and the thickness T_c were changed such that the sum (T_i+T_c) of the thickness T_i and the thickness T_c was maintained constant, and the ratio (T_i/T_c) was as indicated in Table 2.

Examples 12 to 16 and Comparative Example 3

Tires of examples 12 to 16 and comparative example 3 were each obtained in the same manner as for example 1 except that the height H_o was different and the ratio (H_o/H_r) was as indicated in Table 3. In comparative example 3, the position of the inner side end of the inner layer was equal to the contact point P_o in the radial direction.

Examples 17 to 22 and Comparative Example 4

Tires of examples 17 to 22 and comparative example 4 were each obtained in the same manner as for example 1 except that the height H_c was different and the ratio (H_c/H_r) was as indicated in Table 4. In comparative example 4, the position of the outer side end of the chafer was equal to the contact point P_o in the radial direction.

Examples 23 to 28

Tires of examples 23 to 28 were each obtained in the same manner as for example 1 except that the loss tangent LT_i was as indicated in Table 5.

TABLE 4-continued

Evaluation result							
	Comparative example 4	Example 17	Example 18	Example 19	Example 20	Example 21	Example 22
Loss tangent LTo	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Loss tangent LTc	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Rolling resistance	90	90	90	91	93	95	97
Damage-to-bead resistance	75	85	98	100	100	100	100
CSC resistance	200	200	200	200	200	200	200
FCC resistance	100	100	100	100	100	100	100
External damage resistance	100	100	100	100	100	100	100

TABLE 5

Evaluation result						
	Example 23	Example 24	Example 25	Example 26	Example 27	Example 28
Ratio (Hi/Hr)	1.0	1.0	1.0	1.0	1.0	1.0
Ratio (Ho/Hr)	2.0	2.0	2.0	2.0	2.0	2.0
Ratio (Hc/Hr)	4.0	4.0	4.0	4.0	4.0	4.0
Ratio (Ti/Tc)	0.0	1.0	1.0	1.0	1.0	1.0
Loss tangent LTI	0.01	0.02	0.03	0.045	0.05	0.06
Loss tangent LTo	0.07	0.07	0.07	0.07	0.07	0.07
Loss tangent LTc	0.17	0.17	0.17	0.17	0.17	0.17
Rolling resistance	88	90	91	93	95	98
Damage-to- bead resistance	85	95	100	100	100	100
CSC resistance	200	200	200	200	200	200
FCC resistance	100	100	100	100	100	100
External damage resistance	100	100	100	100	100	100

TABLE 6

Evaluation result						
	Example 29	Example 30	Example 31	Example 32	Example 33	Example 34
Ratio (Hi/Hr)	1.0	1.0	1.0	1.0	1.0	1.0
Ratio (Ho/Hr)	2.0	2.0	2.0	2.0	2.0	2.0
Ratio (Hc/Hr)	4.0	4.0	4.0	4.0	4.0	4.0
Ratio (Ti/Tc)	0.0	1.0	1.0	1.0	1.0	1.0
Loss tangent LTI	0.04	0.04	0.04	0.04	0.04	0.04
Loss tangent LTo	0.04	0.05	0.06	0.09	0.10	0.11
Loss tangent LTc	0.17	0.17	0.17	0.17	0.17	0.17
Rolling resistance	90	90	91	93	94	97
Damage-to-bead resistance	100	100	100	100	100	100

TABLE 6-continued

Evaluation result						
	Example 29	Example 30	Example 31	Example 32	Example 33	Example 34
CSC resistance	200	200	200	200	200	200
FCC resistance	100	100	100	100	100	100
External Damage resistance	100	100	100	100	100	100

TABLE 7

Evaluation result						
	Example 35	Example 36	Example 37	Example 38	Example 39	Example 40
Ratio (Hi/Hr)	1.0	1.0	1.0	1.0	1.0	1.0
Ratio (Ho/Hr)	2.0	2.0	2.0	2.0	2.0	2.0
Ratio (Hc/Hr)	4.0	4.0	4.0	4.0	4.0	4.0
Ratio (Ti/Tc)	0.0	1.0	1.0	1.0	1.0	1.0
Loss tangent L _{Ti}	0.04	0.04	0.04	0.04	0.04	0.04
Loss tangent L _{To}	0.07	0.07	0.07	0.07	0.07	0.07
Loss tangent L _{Tc}	0.08	0.10	0.12	0.28	0.30	0.32
Rolling resistance	88	89	91	95	97	99
Damage-to-bead resistance	85	93	100	100	100	100
CSC resistance	200	200	200	200	200	200
FCC resistance	100	100	100	100	100	100
External damage resistance	100	100	100	100	100	100

As indicated in Tables 1 to 7, in the tires of the present invention, rolling resistance is reduced while durability is advantageously maintained. The evaluation result clearly indicates that the present invention is superior.

The tire according to the present invention can be mounted to various vehicles.

The foregoing description is in all aspects illustrative, and various modifications can be devised without departing from the essential features of the invention.

What is claimed is:

1. A pneumatic tire comprising:

- a tread having an outer surface which forms a tread surface;
- a pair of sidewalls that extend almost inward from ends, respectively, of the tread in a radial direction;
- chafers disposed inward of the sidewalls, respectively, in the radial direction; and
- a pair of beads disposed inward of the chafers, respectively, in an axial direction, wherein each bead includes a core, wherein the sidewalls each include an outer layer, and an inner layer disposed inward of the outer layer in the axial direction, the inner layer extends to a region between a corresponding one of the beads and a corresponding one of the chafers,

wherein in the radial direction, an outer side end of the inner layer is disposed outward of an outer side end of the bead,

wherein in the radial direction, an inner side end of the inner layer is disposed inward of an outer side end of the core,

wherein an outer side end of the inner layer reaches the tread, and

wherein the outer layer contacts with a corresponding one of the chafers,

wherein

when Po represents a contact point, on an outer surface of the tire, at which the outer layer and a corresponding one of the chafers contact with each other, an inner side end, in the radial direction, of the outer layer is equal to the contact point Po, in the radial direction, an outer side end of each chafer is disposed outward of the contact point Po, and in the radial direction, an inner side end of the inner layer is disposed inward of the contact point Po,

a loss tangent L_{Ti} of the inner layer is less than a loss tangent L_{To} of the outer layer and a loss tangent L_{Tc} of the chafers, and

a ratio (Hi/12.7 mm) of a height Hi, in the radial direction, from a bead base line BBL to the inner side end of the

- inner layer, relative to a height of 12.7 mm, in the radial direction, from the bead base line BBL to an outer side end of a flange of a rim on which the tire is mounted, is greater than or equal to 0.0 and not greater than 1.5.
2. The pneumatic tire according to claim 1, wherein L1 represents an imaginary line that extends in the axial direction such that a distance, in the radial direction, from the bead base line BBL to the imaginary line L1, is 2.5 times the height 12.7 mm, and Ti represents a thickness, of the inner layer, measured along the imaginary line L1, and Tc represents a thickness, of each chafer, measured along the imaginary line L1, and a ratio (Ti/Tc) of the thickness Ti to the thickness Tc is greater than or equal to 0.5 and not greater than 1.5.
3. The pneumatic tire according to claim 1, wherein when Ho represents a height, in the radial direction, from the bead base line BBL to the contact point Po, a ratio (Ho/12.7 mm) of the height Ho to the height 12.7 mm is greater than or equal to 1.5 and not greater than 3.0.
4. The pneumatic tire according to claim 1, wherein He represents a height, in the radial direction, from the bead base line BBL to the outer side end of each chafer, and a ratio (He/12.7 mm) of the height He to the height 12.7 mm is greater than or equal to 3.0 and not greater than 5.0.
5. The pneumatic tire according to claim 1, wherein the loss tangent LTi is higher than or equal to 0.02 and not higher than 0.05.

6. The pneumatic tire according to claim 1, wherein the loss tangent LTo is higher than or equal to 0.05 and not higher than 0.10.
7. The pneumatic tire according to claim 1, wherein the loss tangent LTc is higher than or equal to 0.10 and not higher than 0.30.
8. The pneumatic tire according to claim 1, wherein L1 represents an imaginary line that extends in the axial direction such that a distance, in the radial direction, from the bead base line BBL to the imaginary line L1 is 2.5 times the height 12.7 mm, and Ti represents a thickness, of the inner layer, measured along the imaginary line L1, wherein the thickness Ti is greater than or equal to 2.0 mm and not greater than 5.5 mm.
9. The pneumatic tire according to claim 1, wherein L1 represents an imaginary line that extends in the axial direction such that a distance, in the radial direction, from the bead base line BBL to the imaginary line L1 is 2.5 times the height 12.7 mm, and Tc represents a thickness, of the chafer measured along the imaginary line L1, wherein the thickness Tc is greater than or equal to 2.0 mm and not greater than 5.5 mm.

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